Influence of Wave Amplitude on the Characteristics of Coupled Motion of a Trimaran equipped with T-foil in Oblique Head Waves

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ABSTRACT

Trimaran vehicles may suffer coupled motions of roll and pitch when navigating in oblique head waves, which will lead to negative effect on navigation safety and comfort. The anti-motion appendage, such as T-foil, may have a positive effect on reducing the roll and pitch motions of the trimaran. However, there is a lack of investigations on the characteristics of the coupled motion of a trimaran equipped with T-foil. In this paper, the key object is to perform a fully nonlinear unsteady RANS simulation to predict the coupled motion of a trimaran equipped with T-foil in oblique head waves, using a commercial RANS solver based on finite volume method. Firstly, the numerical method used in this paper was briefly introduced. Secondly, the numerical method was validated and verified by both the grid convergence test and the comparison with the experimental results. Then the coupled motions of the trimaran equipped with and without a T-foil were investigated covering a range of regular oblique head waves with varying wave amplitudes. Both transfer functions and time histories of the computed motions were used for investigating the characteristics of roll and pitch coupled motion. Different kinds of coupled motion as well as the coupled motion states of the trimaran equipped with the T-foil were analyzed in oblique head waves. The influence of the T-foil on coupled motions of the trimaran was investigated and the effect of different wave amplitudes as well as the forward speed of the trimaran on the characteristics of coupled motion were investigated. The results show that lower forward speed and large wave steepness will lead to roughly coupled motion in oblique head waves and the nonlinear characteristics of ship motions were obvious when suffering coupled motion. T-foil significantly reduces the motion responses and have a positive effect on the coupled motion of the trimaran.

KEY WORDS: Trimaran; T-foil; Coupled motion; Wave amplitude; URANS

INTRODUCTION

Trimaran is one kind of high-performance ship type consisting of a main hull and two side hulls, which exhibits excellent performance in speed, stability, and seakeeping compared with monohull and catamaran (Bertorello et al., 2001; Davis and Holloway, 2007). The seakeeping performance is undoubtedly of vital importance to the vessel and the crew (Fang and Chan, 2007). Trimaran has been of interest of many projects and widely applied in marine engineering. During the past decade, in order to solve the motion problems of the trimaran, large amounts of efforts have been focused on developing experimental and numerical methods to predict the seakeeping performance of trimaran vehicles.

Experimental research is the most effective approach for analyzing ship motions in waves. For the experimental study of the trimaran, most of the studies were focused on the influence of gesture, hull form and outrigger layout on the resistance and seakeeping performance (Bertorello et al., 2001; Begovic et al., 2006; Hebblewhite et al., 2007; Vakilabadi et al., 2014; Deng et al., 2015). Wang et al. (2018) investigated the effects of the stagger and clearance of the side hulls on the motions of a trimaran hull and pointed that a trimaran’s seakeeping performance can be improved by properly designing the outrigger layouts. Nowruzi et al. (2020) conducted a seakeeping test of a trimaran and studied the influence of the position and displacement of the side hulls of the trimaran on the added resistance and ship motions in oblique head waves. However, the model tests were still valuable for consuming lots of effort and time; hence the use of Computational Fluid Dynamics (CFD) method was becoming more and more popular, which can be classified into two main categories namely potential theory and RANS method.

Potential flow theory has been widely applied for calculating motions of trimaran in waves from the beginning of twenty-first century, e.g., 2.5D theory (Duan et al., 2001; Ma et al., 2005; Wei et al., 2007; Duan et al., 2019), and 3D source method (Fang and Too, 2006; Lu et al., 2005). As high-performance computers become more powerful and accessible, it is widely accepted that the CFD method has become more and more popular as a tool for analyzing ship motions in marine industry. Simonsen et al. (2013) stated that RANS methods have advantages and are very good alternatives to the traditional potential theory for the effects which are ignored in the traditional potential theory such as turbulence and viscosity can be directly taken into consideration. RANS method has been applied extensively for solving ship motion problems with different ship types and wave conditions. Kim et al. (2017) carried out numerical predictions for analyzing added resistance and ship motions at various ship speeds and wave steepness for KVLCC2 in head seas. The relationship between the added resistance and vertical ship motions was studied and the non-linearity of the added resistance as well as the motions of ship with varying wave steepness were investigated. CFD method based on the viscous flow theory are

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